Online ISSN: 2588-3526
Journal of Wildlife and Biodiversity
DOI: 10.22120/jwb.2020.124737.1130
Volume 4, issue 4, 1-8 (2020)
(http://www.wildlife-biodiversity.com/)
Scientific Report

A scientific report on Ephemeroptera of Jajrood river, Northern Iran

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Received: 15 April 2020 / Revised: 27 May 2020 / Accepted: 27 May 2020 / Published online: 2 July 2020. Ministry of Sciences, Research and Technology, Arak University, Iran.

Abstract
Mayflies, order Ephemeroptera compose one of the main habitats of all the aqua systems worldwide, which has valuable roles in several food chains. In this study, species diversity of Ephemeroptera in Jajrood River (Hajiabad, Saeidabad, and Khojir areas), eastern Tehran Province, was studied spring-summer, 2016. Samples were collected weekly and kept in Ethanol 80% for taxonomic identification. One hundred forty-nine samples belonged to 17 species, under seven genera in four families (*Baetidae*, *Heptageniidae*, *Habrophlebidae*, and *Isonychiidae*) were collected. The majority of species abundance (45.63%) obtained from Khojir, although Hajiabad with 11 different species showed a more diverse collection for Ephemeroptera. Among the collected species, *Heptagenia lateralis*, *Isonychia shima*, *Habrophlebia lauta*, *Labiobaetis atrebalinus*, *Labiobaetis potamoticus*, *Labiobaetis glaucus*, and *Baetis atlanticus* were reported for the first time for Iran fauna and *Baetis fauscatus* and *Baetisrhodani*were the most common species. According to diversity indices, the Khojir area along the River showed higher species collection. Knowledge of the species diversity in aqua systems in urban areas like Jajrood River would lead to new insight into ecosystem preservation and better management decisions.

Keywords: Ephemeroptera, Jajrood river, species diversity

Introduction
Ephemeroptera (Mayflies), as a rich-species class, has a worldwide distribution with a great collection for the Iran fauna. These unique species compose one of the primary organisms of all the aquatic systems around the world. In previous studies on the species variation of Ephemeropteran in Iran, 46 species belonging to 25 genera have been reported from different parts of the country (Bojkova *et al.* 2018). A recent checklist of Iranian Ephemeroptera showed that the vast majority of collected species were limited to Iran's northern part (Alborz Mountains and its surroundings). Through a comprehensive study on the aquatic species of Iran in addition to some parts of neighboring countries such as Iraq, Azerbaijan, Turkemanestan, Afghaniatan, and Pakistan, Mohammadian (2005) showed that Ephemeroptera could be one of the most abundant and diversified groups of the aquatic residents which could not be a reliable resource for Iranian Ephemeroptera. Moreover, most of the studies on

Ephemeroptera in Iran have focused on the ecological features of the aquatic habitats and the water quality effects; and reported this class as the main group of benthic macro-invertebrates.

In a comprehensive review of the previous studies about the benthic macro-invertebrates, Sharifinia (2015) reported 37 Ephemeropteran samples from Iranian Rivers, which were identified to species or genus level. Shayeghi *et al.* (2014) assessed the fauna of aquatic insects for possible use for Malaria vector control in the Karaj River. They reported Ephemeroptera as one of the three orders live in the area. A similar report was admitted in the other studies in different parts of the country such as east of Golestan Province (Eyidozehi *et al.* 2014), Zayandehrood River in Isfahan Province (Ghane 2013), Cheshmeh Kileh in Guilan Province (Abbaspour *et al.* 2013a, 2013b) and Mohammad Abad River in Golestan Province (Farhangi and Teymouri Yansari 2011). Kamali and Tatina (2010) presented Ephemeroptera as the most abundant taxon in Lamir River in the Talesh area, Guilan Province.

Some studies focused on the taxon classification of species and genus levels. Mousavi and Hakobyan (2017) studied the fauna of Ephemeroptera, Plecoptera, and Trichoptera from some water bodies in Mazandaran Province and reported ten species in 5 genera, including *Cloeonsp*, *Oligoneuriella*, *Epeorus*, *Ephemerella*and *Caenis* belonging to 5 families. Sharifinia *et al.* (2016) evaluated the pollution level in Shahrood River in Qazvin Province and its effect on the reported some genera, including *Ameletus, Baetis, Ecdyonurus, Cinygmula*, and *Sernitella.* Ebrahimi *et al.* (2014) recorded five Ephemeropteran species in four families, including *Baetidae, Caenidae, Ecdyonuridae,* and *Ephemerellidae* for Zayandehroud River. Farasat and Sharifi (2014) reported three genera, including *Baetis, Ephemerella,* and *Maccaffertium,* for macro-invertebrates benthic fauna of Kavat Stream, Western Iran. Mahboobi Soofiani *et al.* (2012) studied the macro-invertebrates of Zayandehroud River and reported 15 genera belonging to 7 families. Jacobus *et al.* (2009) reported *Serratella brevicauda* and *S. elissa* for the first time for Iran fauna, which was published from China, too. Poorali Darestani (2009) reported three genera of *Baetis*, *Cloeon,* and *Caenis* from Cheshmeh Ali in the Damghan area. Dehghani *et al.* (2004) studied the aquatic insects of the Kashan area and reported that Ephemeroptera compromised 7 % of the total samples, which were mostly included of two genera, *Baetis* and *Heptagena*.

In a unique study in Jajrood River, 42% of the total fauna population belonged to Ephemeroptera in five families, Baetidae, Heptageniidae, Caeniidae, Leptophlebiidae, and Oligoneuriidae and 7 genera, *Baetis, Cloeon, Epeorus, Rhithrogena, Caenis, Paraleptophlebia* and *Lachlania* (Amri *et al.* 2014), but according to Bojkova *et al*. (2018), as there was reported many species known for Nearctic and Neotropic Regions, the occurrence of these species should be excluded from Iran fauna.

It is expected that Iran, as the second-largest country of the Middle East after Saudi Arabia, has a rich collection of the Ephemeropteran fauna. Iran should be viewed as a specific transitory zone hosting West Palaearctic (European) and Caucasian elements of fauna on one hand and Central Asian or even Oriental faunal elements on the other being undoubtedly worth of the detailed and extensive study (Bojkova *et al*. 2018). There is a great need to identify Ephemeroptera species richness throughout the country, and this study was conducted to determine Ephemeroptera fauna in Jajrood River, east of Tehran Province.

Findings

In this study, a totally of 149 samples were collected and classified into 17 species belonging to 7 genera under three different families of Ephemeroptera from Jajrood River.

Among the collected samples, seven species, *Heptagenia lateralis, Isonychia shima, Habrophlebia lauta, Labiobaetis atrebalinus, Labiobaetis potamoticus, Labiobaetis glaucus,* and *Baetisat lanticus* were reported for the first time for Iran fauna. However, they have been previously reported at the genus level from Iran that will be noticed separately for each species. All of the collected species are as the following:

Heptageniidae:
Heptagenia lateralis McDunnough, 1924
The genus *Heptagenia* has already been reported from Iran in the Karaj River (Shayeghi *et al.* 2014), Zayandehrud River in Isfahan (Ebrahimi *et al.* 2014, Ghane 2013, Ebrahimnezhad and Nikoo 2004) and Shamrood River in Guilan (Rahimibashar *et al.* 2015). The species has previously been reported from Turkey (Salur *et al.* 2016, Kazanci and Turkmen 2012, Tanatmis 2002), Black sea basin (Petrovic *et al.* 2015). The species was collected from Hajiabad in Jajrood River (Table 1), and this is its first report for the Iran fauna.

Isonychidae:
Isonychia shima Matsumura, 1931
This Japanese species have been classified as *Prionoides shima* and recently transferred to *Isonychia* species (Tiunova *et al.* 2004). The species was collected from Hajiabad in the Jajrood River (Table 1). This is the first report of this species from Iran

Habrophlebiidae:
Habrophlebia lauta McLachlan, 1884
This Palearctic species has been recorded from Turkey, Europe (Haybach and Malzacher 2002), and North Africa and recently was reported from Guilan Province, Iran (Bojkova *et al.* 2018). Ebrahimnezhad and Nikoo (2004) reported the genus *Habrophlebia* from Marbor River, Isfahan Province. Aydinli (2017) reported the species from the black sea area in Turkey. This species was collected for the Iranian fauna from Hajiabad in Jajrood River (Table 1)

Baetidae:
Labiobaetis atrebalinus Eaton 1870
The species has been collected from Turkey (Aydinli and Ertorun 2015). The genus has been reported from Khuzestan Province in Iran (Sroka *et al.* 2019). This is the first report of the species from Iran, in Hajiabad and Jajrood sampling points in Jajrood River (Table 1).

Labiobaetis potamoticus Gattolliat and Al Dhafer 2018
The species has been reported from Saudi Arabia (Gattoliat *et al.* 2018). The genus has been reported from Khuzestan Province in Iran (Sroka *et al.* 2019). This is the first report of Iran's species in Khojir sampling points in the Jajrood River (Table 1).

Labiobaetis glaucus, Agnew 1961
These Palearctic species have been reported from Saudi Arabia (Gattoliat *et al.* 2018). The genus has been reported from Khuzestan Province in Iran (Sroka *et al.* 2019). This is the first report of the species from Iran, Khojir in Jajrood River (Table 1).

Centroptillum luteolum, Otto Friedrich Müller, 1776
This species has been collected from Turkey (Aydinli and Ertorun 2015), Germany (Haybach and Malzacher 2002), and Serbia (Petrovic *et al.* 2015). This species was previously reported from Iran, but the exact sampling area did not mention (Mohammadian 2005). This was collected from Hajiabad, Khojir, and Saeidabad sampling point in the Jajrood River (Table 1).

Procloeon capsicum sp.n.
This species has been referred to as *Pseudocentroptillum capsicum* (Bojkva *et al.* 2018) and reported from Guilan Province. In this study, just one sample was collected belonged to this species from the Hajiabad point (Table 1).

Baetis barokianus, Thomas and Dia1984
This Mediterranean species was previously

reported from Cyprus (Godunko *et al.* 2017), Lebanon (Godunku *et al.* 2017) and Iran, Siahrud River in Roudbar country, and Sardar Jangal district from Masouleh city (Bojkova *et al.* 2018). In this study, the samples collected from Hajiabad and Khojir have belonged to this species (Table 1).

Baetis rhodani, Pictet, 1843
The species is widely distributed in the western Palearctic region and has been reported from different countries in the Middle East and Mediterranean areas such as Turkey (Aydinli 2017, Aydinli and Ertorun 2015, Turkmen and Kazanci 2013) and Europe like Germany (Haybach and Malzacher 2002) and Serbia (Petrovic *et al.* 2015). In Iran, it was collected from the bottom substrate of Zarrinehrud River in the west of Azarbaijan Province and Karaj River in Alborz Province (referred to Bojkova *et al.* 2018); in addition to the previous reports, in the last Ephemeropteran study in Iran, it was collected from Guilan and Ardabil Provinces, too. Ebrahimi *et al.* (2014) reported *B. rhodani* from the Zayandehrud River in Isfahan. In this study, the species was reported from all the sampling points, mostly from Saeidabad (Table 1)

Baetis fuscatus, Linnaeus 1761
This Transpalearctic or Holarctic species was collected as a new record from Guilan Province (Bojkova *et al.* 2018).it was from different parts of the world such as Turkey (Turkmen and Kzanci 2013, Aydinli and Ertorun 2015 and Aydinli 2017), Germany (Haybach and Malzacher 2002), and Serbia (Petrovic *et al.* 2015). In this study, the species was reported from Hajiabad and Khojir sampling areas, mostly in Hajiabad (Table 1).

Baetis atlanticus Soldán and Godunko 2006
This species was collected first in Portugal as a new species and was known as conspecific with *B. rhodani* (Soldan and Godunko 2006). Six samples of the species were collected from the Khojir sampling point in two sampling times, and this is the first report of the species for Iran fauna (Table 1).

Baetis (*Nigrobaetis*) *muticus* Linnaeus 1758
The species mainly belonged to Kazakhstan and was reported from Turkey's black sea area (Aydinli 2017). In Iran, it was reported previously from Mazandaran Province in Chatan River, Guilan Province, and Ardabil Province (Bojkova *et al.* 2018). In this study, Two samples of the species were collected from the Jajrood River (Table 1).

Baetis gemellus Eaton 1885
This species has been collected from the eastern part of the Black Sea in Turkey (Turkmen and Kazanci 2013), and Similar samples to this species have been previously reported from Ardebil and Guilan Provinces of Iran, which were categorized as *Baetis vadimi*. This is the first report of the species in Iran. In this study, samples belonging to this species were collected from the Khojir point (Table 1).

Baetis lutheri Muller-Liebenau 1967
This species is widely distributed from Europe to the Caucasus, Turkey (Kazancı and Türkmen 2012, Turkmen and Kazanci 2013, Aydinli and Ertorun 2015, Salur *et al.* 2016, Aydinli 2017), Germany (Haybach and Malzacher 2002) and Iraq (Al-Zubaidi *et al*. 1987) and recently reported from Guilan and Ardebil Provinces in Iran (Bojkova *et al.* 2018). Khojir and Saeidabad had five samples of this species (Table 1).

Baetis melanonyx Pictet 1843
This species has been reported from Germany (Haybach and Malzacher 2002), and previously it was collected from Sefidrud River in Roudbar County (Godunko *et al.* 2017), but it was not reported officially. In this study, larvae of this species were collected from Khojir and Hajiabad (Table 1).

Baetis tricaudatus, Dodds 1923
The species was reported from the Jajrood River (Amri *et al.* 2014).In this study, three larvae belonging to this species were collected

from the Hajiabad sampling point (Table 1).

Table 1. Samples collected from different sampling dates with notification of their sampling locations and the species frequency (No.) with frequency percentage

Species	Sampling time through spring and summer				Total samples collected	Frequency percentage
	April	May	June	July		
Heptagenia lateralis		3 Hajiabad			3	2.01
Isonychia shima		1 Hajiabad			1	0.67
Habrophlebia lauta			1 Hajiabad		1	0.67
Labiobaetis atrebalinus		6 Saeidabad 4 Hajiabad	5 Saeidabad		15	10.06
Labiobaetis potamoticus		1 Khojir			1	0.67
Labiobaetis glaucus			6 Khojir		6	4.02
Pseudocentroptiloides capsicum	1 Hajiabad				1	0.67
Centroptillum luteolum		3 Saeidabad	1 Hajiabad	1 Khojir	5	3.35
Baetis barokianus	1 Khojir		1 Khojir 1 Hajiabad	2 Hajiabad	5	3.35
Baetis rhodani	1 Saeidabad 2 Khojir 2 Hajiabad	19 Saeidabad 1 Hajiabad 2 Khojir	2 Khojir 9 Hajiabad	2 Hajiabad	40	26.84
Baetis fuscatus	1 Hajiabad	3 Khojir 24 Hajiabad	2 Hajiabad	4 Khojir 10 Hajiabad	44	29.53
Baetis atlanticus	3 Khojir		3 Khojir		6	4.03
Baetis muticus			2 Saeidabad		2	1.34
Baetis gemellus		1 Khojir			1	0.67
Baetis lutheri	1 Khojir 4 Saeidabad				5	3.35
Baetis melanonyx			6 Khojir 3 Hajiabad	1 Hajiabad	10	6.71
Baetis tricaudatus			3 Hajiabad		3	2.01
SUM	16	68	45	20	149	

As can be seen in Table 1, most of the samples were collected through May-June. Larvae were found in all the sampling points with varied diversity and abundance. But decreasing the collected samples' frequency could be observed through summer months, especially in July, which could be due to high temperatures or high concentrations of water pollution or predation by fish or other aquatic predators.

Table 2. Shannon and Simpson indices for the sampling areas

Sampling area	Species No.	No.	Species frequency (%)	(Simpson Index)D	(Shannon Index)H
Hajiabad	11	72	29.53	3.064	1.525
Khojir	10	37	24.83	7.1994	1.762
Saeidabad	5	40	45.63	2.909	1.275
Total	-	149	100	-	-

Diversity indices are used to determine the species diversity in a given area, and it could be used to compare species diversity among similar areas. As can be seen in Table 2, Shannon and Simpson's indices revealed different results for the sampling area.

According to the Shannon index, Khojir had the most abundant species diversity, and the highest calculated H index (1.762) would be discussed regarding the partial high Simpson index (7.1994) with ten species. On the other hand, Saeidabad had the lowest Simpson index as (2.909) parallel with the lowest Shannon index (1.275), composing a high quantity (45.63%)of all the collected samples. Sorenson's Coefficient was calculated for two pair of areas separately, CC was calculated for Khojir and Saeidabad areas as 0.434, for Hajiabad and Saeidabad as 0.285 and Hajiabad and Khojir as 0.285 (Table 2).

According to the results, 17 species were collected from three areas along the Jajrood River in three sampling areas Saeidabad, Hajiabad, and Khojir. According to the recent review studies, a great checklist of 46 species belonging to 25 genera of Iranian Ephemeroptera has been reported (Bojkova *et al.* 2018). Other similar studies showed the great importance of Ephemeroptera biodiversity in different aqua systems of Iran such as rivers in Lar Park (Salavatian *et al.* 2011), Zayandehrood River (Mahboobi Soofiani *et al.* 2012), Shadegan Lagoon (Nasirian *et al.*, 2014), and Jajrood River (Amri *et al.* 2014). Several studies mentioned that water pollution, water depth, and water warmth would be the main factors affecting the macro-organisms of aqua systems (Mahboobi Soofiani *et al.* 2012, Shalbaf *et al.* 2012, Nasirian *et al.* 2014, Sharifinia *et al.* 2016). So besides the water pollution, the abiotic factors of the aqua-system should be considered as the effective factors on Ephemeroptera diversity and abundance.

The results of the present study showed that Jajrood River in the eastern part of Tehran Province could be a valuable reservoir for Ephemeroptera species, which is needed to be reserved and protected against chemical pollution from urban areas along the River. Khojir area showed more Ephemeroptera species collection that would be due to less infection or higher organic materials in water. Sampling through Jajrood River added seven new species to the Iran fauna, which would be used in future studies about environmental protection and fish farming.

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